Combining Kalman Filter with Mixture Color Model Tracking of Pallet Image

Ssu-Wei Chen, Luke K. Wang, Jen-Hong Lan, and Jia-Lin Tu

***Abstract*—In this paper, we propose combining the mixture color model with Kalman filter method. The purpose is to enable forklifts to search for pallets, but it is able to meet fully automated system with real-time. We focused on pallets for image feature and tracking. First, we manually segmented 30 pallet images and statistics of the best color threshold, this method must find the threshold of different color space and mixture of two important color spaces containing HSV and YCbCr, we extracted the H and the Cb composition mixtures to find the best color threshold, and using a combination of Kalman filter(KF) and the color model method to track pallet images, we then used the logic function to keep our information after obtaining the color image segmentation, the noise of the image must be removed, this algorithm can be used on video sequences efficiently. Finally, experimental results show that the method has effective tracking pallet images in the video sequences.**

***Index Terms*—Kalman filter, color space, object tracking, image detection.**

I. Introduction

Image tracking is one of the important missions in the image process and computer vision field. In this paper, we focus on color image tracking, it can be divided into two categories, one is based on color space division, the other is to use KF algorithm. In the color space segmentation method, often used in color space are RGB,YCbCr,HSV and so on. Although the RGB color space is the most direct expression of the form, it is not necessarily suitable for color analysis[1], the YCbCr and HSV have good effect in some applications and has often used algorithms in recent years[2][3][4]. The clustering method in recent years than the classic method is K-means, it is not only the data clustering classification, the color can also be classified[5].In this paper, we use the threshold of the color space as the features value of the KF, due to the pallet image colors being similar to skin color, we refer to [6], this is the use of statistical skin color distribution method in different color space, to find the closest color of the threshold. In our method, we measured the pallet images in different color space to find the color of threshold, and then into the KF after the operation, to find the location of pallet images.

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In recent years, the new object tracking algorithms have been proposed, object tracking algorithms are often used including shift, optical flow, Kalman filter[7] etc. Shift algorithm has good recognition rates and high accuracy, but if the camera lens or tracking object is moving too fast, this will lead to an inaccurate algorithm[8]. Due to the optical flows large algorithm size, it is generally better to use a simple one for background tracking[9].

KF has a lot of methods that have been proposed.[10] used KF to measure the similarity with RGB color-based approach between moving objects, and the threshold is applied to measure the similarity between the detected regions.[11] used KF in distributed tracking system for tracking multiple moving people in a room using cameras.[12] used KF to track contours of nonrigid objects, it's employed an optical-flow mesurements and a KF to detect objects. Fig.1 is a complete diagram of the hardware and software equipment for real-world.

The rest of this paper is organized as follows. Section II describes the basic image process method and Kalman filter in the past. Section III describes the proposed method, including color statistics and experimental procedure. Section IV describes experimental results. Finally, section V presents our conclusions.

Fig. 1. The hardware and software equipment

II. PREVIOUS WORKS

A. Basics of Edge Detection

In the past, many of the image edge detection have been proposed. Edge detection is often widely used in image segmentation of the pre-treatment, it is used to find the contour of objects and then find the target by other methods, there are many edge detection methods that have been proposed, such as Sobel, Canny, Prewitt operators and so on. Fig.2 shows the Sobel and Prewitt operators.

-1	-1	-1	-1	0	-1	-1	-2	-1	-1	0	1
0	0	0	-1	0	-1	0	0	0	-2	0	2
-1	-1	-1	-1	0	-1	1	2	1	-1	0	1

(a) (b)

Fig. 2. Edge detection operators (a) Prewitt operator (b) Sobel operator

Prewitt and Sobel operators are the most commonly used to compute the digital gradient, the Prewitt mask is easier to implement, but Sobel is better to remove noise.

B. Color space Conversion

The traditional color space would be divided into three categories, including the RGB, YCbCr, HSV and so on. The RGB is the most basic color, it can convert to other color spaces, the HSV color space is divided into three elements, H is the hue, S is the saturation and V is the brightness respectively, RGB to HSV mathematical is as follows:

$$H = \begin{cases} H_1 & \text{if } B \leq G \\ 360 - H_1 & \text{otherwise} \end{cases} \quad (1)$$

$$S = \frac{\text{Max}(R,G,B) - \text{Min}(R,G,B)}{\text{Max}(R+G+B)} \quad (2)$$

$$V = \frac{\text{Max}(R,G,B)}{255} \quad (3)$$

Which N is the total number of pixel of the image, the N_q is the pixel intensity level the number of r_q, L is the image intensity of the total number of all possible. Assuming a threshold value K selected , the C_0 is the intensity in the (0,1,...,K-1),a collection of pixels, while C_1 is the intensity(k,k+1,...,L-1) in a collection of pixels. Otsu methods to obtain the maximum between-class variance σ_S^2 for the critical value K, this variable is defined as follows:

$$Y = 0.299R + 0.587G + 0114B \quad (4)$$

$$Cb = -0.147R - 0.289G + 0.436B \quad (5)$$

$$Cr = 0.615R - 0.515G - 0.100B \quad (6)$$

Morphological erosion and dilation in the image processing is an important foundation. Dilation is the image of the object's mathematical computing size, the dilation is a collection of the operations defined.

$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \emptyset\} \quad (7)$$

where $\emptyset$ the empty set and B as structural elements. The erosion is the image of objects smaller or thinner, erosion and dilation similar to the mathematical definition.

$$A \ominus B = \{z | (B)_z \cap A^c \neq \emptyset\} \quad (8)$$

Erosion of A by B is a structural element of the origin of all the set positions, in which translation of the B and A's background does not overlap.

C. Basics of Kalman Filter

Kalman filter is an estimator that predicts and corrects the states of linear processes. The typical Kalman filter process is guided by the following linear difference equation and measurement equation:

$$x_k = Ax_{k-1} + w_{k-1} \quad (9)$$

$$z_k = Hx_k + v_k \quad (10)$$

where x_k and z_k represent the state and the measurement at time K, A is the transition matrix and H is the measurement matrix. w_{k-1} and v_k represent the Gaussian process noise and the Gaussian measurement noise. They are normal probability distributions and independent of each other:

$$P(w) \sim N(0, Q) \quad (11)$$

$$P(v) \sim N(0, R) \quad (12$$

Kalman filter consist of two steps, time update equations and measurement update equations. Time update equations contain two mathematical equations, a prior estimate of state $\hat{x}_k^-$ and error covariance P_k^-estimate is obtained for the next time step k.

$$\hat{x}_k^- = A\hat{x}_{k-1} + w_k \quad (13)$$

$$P_k^- = AP_{k-1}A^T + Q \quad (14)$$

The measurement update equations are responsible for the feedback:

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \quad (15)$$

$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-) \quad (16)$$

$$P_k = (I - K_k H)P_k^- \quad (17)$$

where K is Kalman gain, R is measurement variance matrix.

III. THE PROPOSED METHOD

The traditional color image segmentation generally used the color space converter method. First, we compute the color distribution to statistics for block of interest, we used the 30 pallet images statistics color distribution, including HSV and YCbCr color space and then extracted H and Cb component, we used the logic function separation color and then used mathematical morphological noise removal. Second, after the removal of noise, we must match the color characteristics with the KF algorithm to complrte a system. Finally, we successfully tracked pallet images. Fig. 3 shows the basic process of the algorithm in this paper.

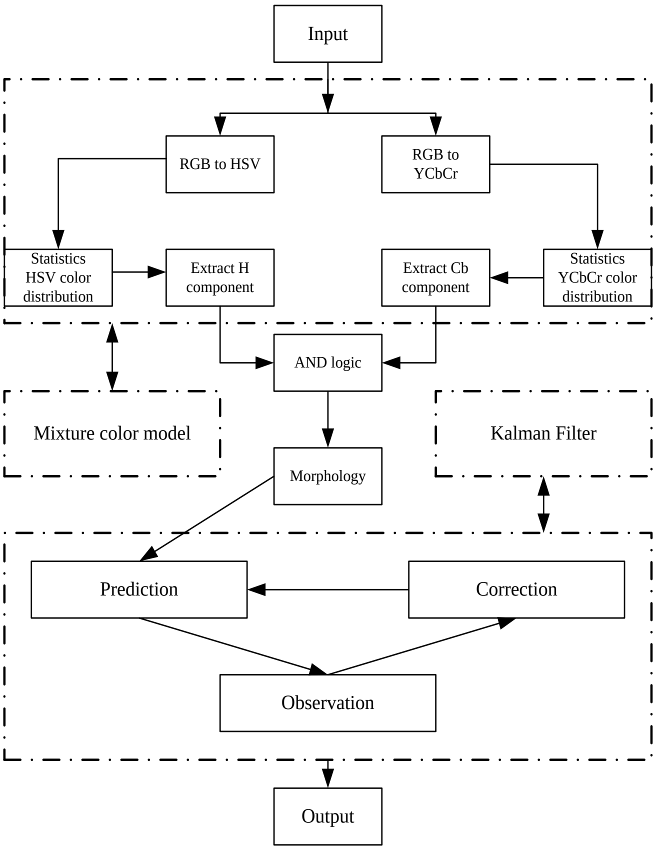


Fig. 3. Flow chart of the proposed method

A. *Color Feature Extraction*

We collected 30 pallet images and statistics color distribution on RGB, YCbCr, HSV color model respectively. Fig. 4 show that the 30 pallet images.

Fig. 4. The pallet images database

Fig. 5 shows several kinds of different pallet image color distribution. Fig. 5 (a) (b) (f) is not a good result, because the color is too widely distributed. We decided to compare Fig. 5 (c) (d) (e) the segmentation results. Fig. 5 (c) is the CbCr color space, we can clearly see the color distribution of the threshold Cb is between 85 to 155 and Cr is between 110 to 165. .Fig. 5 (d) is the Hcb color space, H is between 0 to 0.2 and Cb is between 85 to 155, due to the color distribution is not significant, we reset the Cb between 85 to 130. Fig. 5 (e) is the HCr color space, H is between 0 to 0.2 and Cr is between 130 to 170.

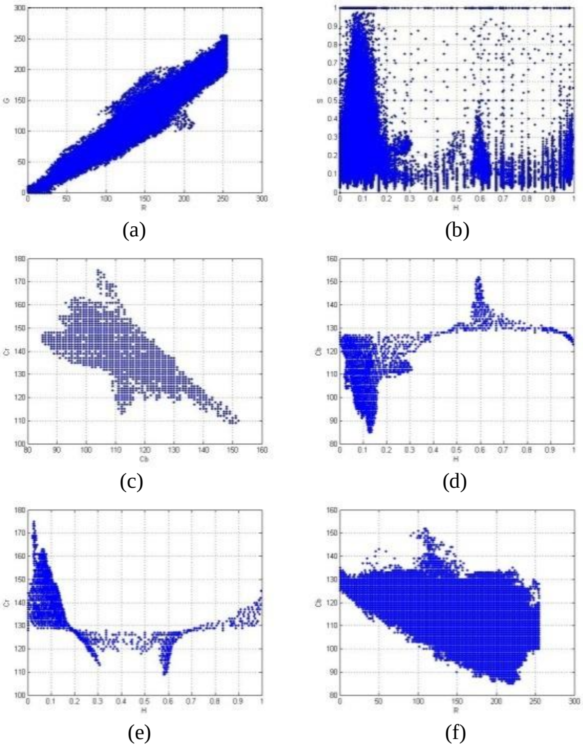


Fig. 5. The color distribution of 2D projection (a) a 2D projection in the GB color space (b) a 2D projection in the HS color space (c) a 2D projection in the CbCr color space (d) a 2D projection in the HCb color space (e) a 2D projection in the HCr color space (f) a 2D projection in the RCb color space.

We can define a mathematical HCb color space as follows:

$$\mathrm{HCb} = \begin{cases} 1 & 0 \le \mathrm{H} \le 0.2 \text{ and } 85 \le \mathrm{Cb} \le 130 \\ 0 & \text{otherwise} \end{cases} \tag{18}$$

Comparison of experimental results in section IV.

B. *Combining KF and Color Model*

In this paper, we combined KF and color model tracking of objects. KF not only has the advantages of fast calculation speed and accurate prediction rate, but it can also be used with a variety of different features to tracking, before the start of the algorithm, we must set the initial value. The initial value settings are as follows:

$$A = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{19}$$

$$Q = \begin{bmatrix} 150 & 0 & 1 & 0 & 0 & 0 \\ 0 & 150 & 0 & 1 & 0 & 0 \\ 0 & 0 & 2 & 0 & 1 & 0 \\ 0 & 0 & 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 \end{bmatrix} \tag{20}$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{21}$$

$$R = \begin{bmatrix} 0.3 & 0 \\ 0 & 0.3 \end{bmatrix} \tag{22}$$

$$I = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (23)$$

KF used for tracking is defined in terms of its state, motion model, x_k is a six-dimensional system state vector, which can be expressed as:

$$x_k = [x_0, y_0, v_{x,k}, v_{y,k}, a_{x,k}, a_{y,k}] \quad (24)$$

where x_0, y_0 represent horizontal and vertical centroid coordinates, $v_{x,k}$ and $v_{y,k}$ is the speed, $a_{x,k}$ and $a_{y,k}$ is the acceleration. After the state equation and measurement equation of motion model are defined,in a small range, KF can be used to estimate the object's size and location in the next frame. According to the equation (13), (14) to calculate the new prediction range, we must find the correct target and then continue to the next step. As shown in equation (15), (16), (17). Last, the process goes back to the prediction steps and continues the cycle. Table.I shows the complete algorithm of this article.

TABLE I: ALOGORITHM OF THE KALMAN FILTER

Kalman filter with mixture color model
Set the initial values and constants
A,B,H,Q,R,$\hat{x}_0$, p_0
Step1
Calculate the new forecast range, according to equation (13), (14).
Step2
According to equation (18), find the correct target , the use of mixtures color model as the features.
Step3
If the target is found to record in the z_k, and skip to step5.
Step4
If the prediction has still not found the object, we need to search for the object of the whole image, to record in z_k.
Step5
According to equation (15), calculate the Kalman gain.
Step6
According to equation (16), update state estimate.
Step7
According to equation (17), update state covariance matrix.
Step8
Go back to step1, continue the cycle.

IV. EXPERIMENTAL RESULTS

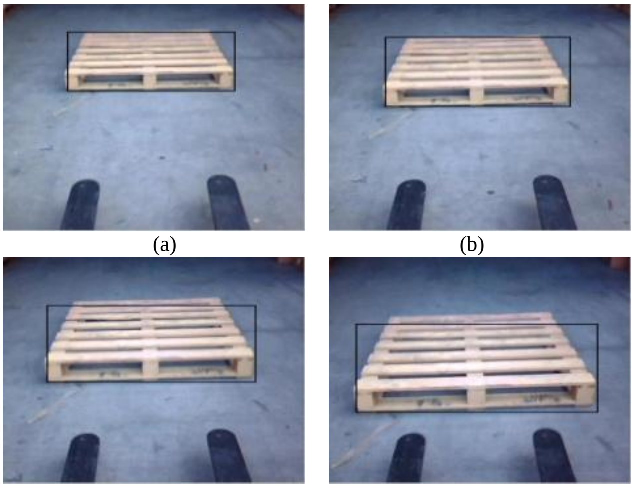
In this section, we show experimental results of the proposed image detection and tracking method. The proposed algorithm was implemented in MATLAB 7.6(2008a). The webcam used Logitech C200, and tested in windows XP SP3 with Intel dual core I5 CPU with a memory of 6GB. Table.II shows all image and video formats. Fig.6 shows different color space segmentation. We compared the results of HCb, CbCr and the HCr, Hcb had the best results, then the other two methods could not completely eliminate noise. Fig.7 shows the video sequences of pallet image detection. Fig.8 and Fig.9 we tracked a red object using the KF without the mixed color model, it used a single color model, we focused on a red feature, no other color features. Fig.10 and Fig.11 is a study proposed in this article, we used two real-time videos for pallet images, the experimental results show that we have a good tracking effect.

TABLE II: VIDEO AND IMAGE FORMAT

Video and image description			
Video name	Number of frames	Video type	Algorithm type
Pallet image1 Fig.6	1	Non real-time	Mixture color model
Pallet image2 Fig.7	100	Non real-time	Mixture color model
Red object tracking1 Fig.8	200	Real-time	KF with color model
Red object tracking2 Fig.9	200	Real-time	KF with color model
Pallet image tracking1 Fig.10	390	Real-time	KF with Mixture color model
Pallet image tracking2 Fig.11	561	Real-time	KF with Mixture color model

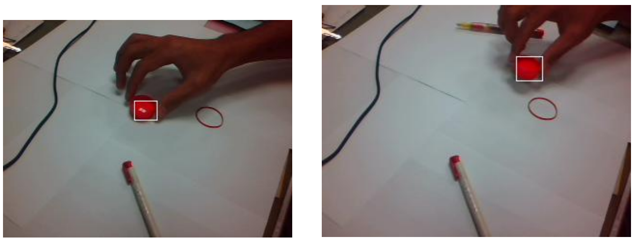
(a) (b) (c)

Fig. 6. The different color space segmentation (a) The HCb color space (b) The CbCr color space (c) The Hcr color space.

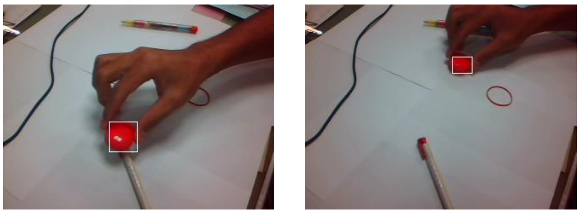


(a) (b) (c) (d)

Fig. 7. The video sequences of pallet image detection (a) The 1th frame (b) The 50th frame (c) The 75th frame (d) The 100th frame .

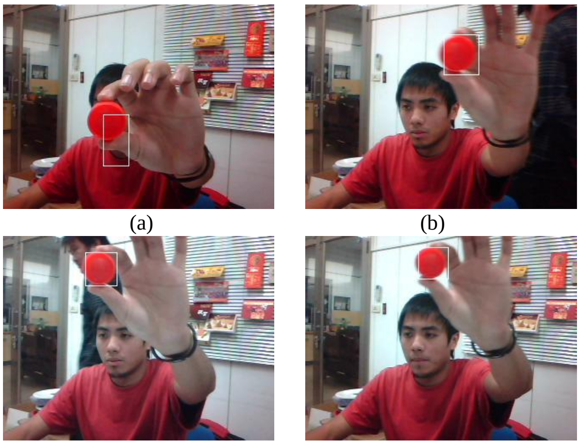


(a) (b)



(c) (d)

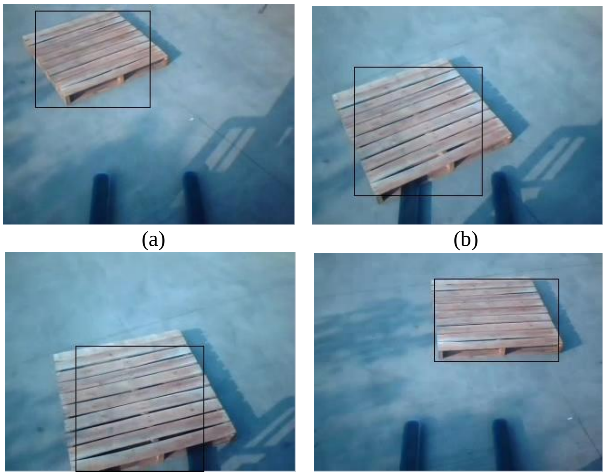
Fig. 8. Single color model with KF methods (a) The 1th frame (b) The 50th frame (c) The 150th frame (d) The 200th frame.



(a) (b)

(c) (d)

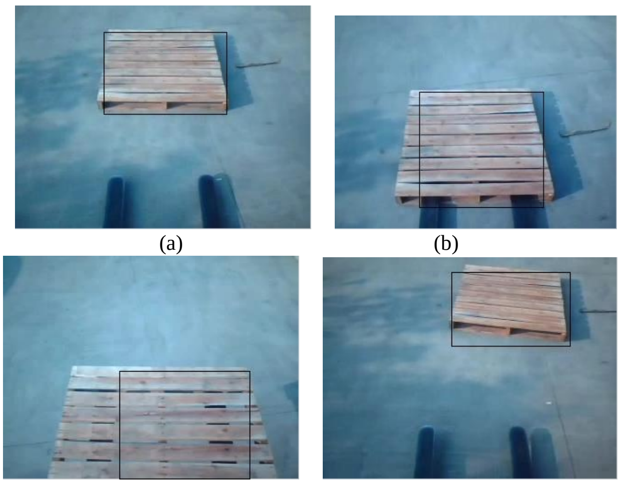
Fig. 9. Single color model with KF methods (a) The 1th frame (b) The 50th frame (c) The 150th frame (d) The 200th frame.



(a) (b)

(c) (d)

Fig. 10. KF with mixture color model methods (a) The 10th frame (b) The 100th frame (c) The 130th frame (d) The 390th frame.



(a) (b)

(c) (d)

Fig. 11. KF with mixture color model methods (a) The 1th frame (b) The 63th frame (c) The 290th frame (d) The 561th frame.

V. Conclusion

In this paper, we successfully used mixture color space with KF application in image detection and tracking. We have a total of six color space statistics, three color space marked effects, the effect is not significant in the other three experiments. In our approach, the image detection and tracking was successful. We combined the forklift and webcam to track and meet real-time video. In the future, we will combine more algorithms to track, faster with more accurate experimental results.

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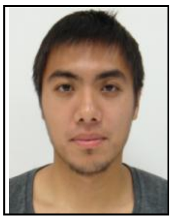

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